2014 STATE OF THE LAKES UPDATE

SUNDAY LAKE

REPORT DESCRIPTION

This report is an update on the health of Sunday Lake based on water quality data collected from 1990 through 2014 by local volunteers and Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Sunday Lake, please visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Sunday Lake is a 49-acre lake located west of Interstate 5 and east of Stanwood. The lake is shallow, with a maximum depth of 5.8 meters (19 feet). One main stream (sometimes called Jackson Gulch) enters at the west end of the lake. The lake outlet flows east and then south to the Stillaguamish River. The development pattern around the lake shore is irregular, with some areas of dense homes and other areas of large undeveloped lots. There are about 30 homes around the lake shore. The lake watershed, which is the land area that drains to the lake, is relatively large—about 13 times the size of the lake. This means that there is a greater potential for pollution impacts from the watershed than at a lake with a small watershed.

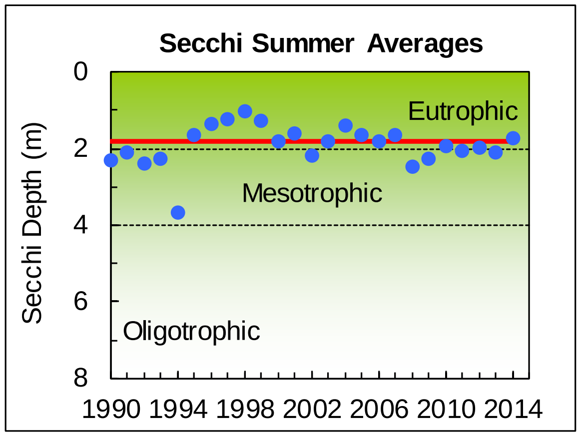
LAKE CONDITIONS

The following graphs illustrate the summer averages and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for Sunday Lake. Please refer to the table at the end of the report for long-term averages and for averages and ranges for individual years.

Water Clarity

The water clarity of a lake, measured with a Secchi disk, is a reading of how far one can see into the water. Water clarity is affected by the amount of algae and sediment in the lake, as well as by water color. Lakes with high water clarity usually have low amounts of algae, while lakes with poor water clarity often have excessive amounts of algae.

Water clarity in Sunday Lake is low, with a long-term 1990 - 2014 summer average of 1.9 meters (6 feet). In 2008 and 2009, water clarity was improved, averaging 2.5 and 2.3 meters, respectively. However, the summer averages from 2010 through 2014 have been close to the long-term average. Overall, between 1990 and 2014 there has been no trend in water clarity.



Water Color

The color of lake water affects water clarity and the depths at which algae and plants can grow. In many lakes, the water is naturally brown, orange, or yellow. This darker color comes from dissolved humic compounds from surrounding wetlands and does not harm water quality. Measurements of true water color provide clues to changes in water clarity. True water color is only the color from dissolved materials and not of the color of algae or sediment suspended in the water.

The water color of Sunday Lake averaged 37 pcu (platinum-cobalt color units) in 2010 – 2011, which indicates a moderate amount of color in the lake water. The natural brown color of the lake water is part of the reason why Sunday Lake exhibits low water clarity.

SUNDAY LAKE

Temperature

The temperature of lake water changes with the seasons and varies with depth. During spring and summer, the sun warms the upper waters. Because warmer water is less dense, it floats above the cooler, denser water below. The temperature and density differences create distinct layers of water in the lake, and these layers do not mix easily. This process is called stratification and occurs during the warm months. The warm, upper water layer is called the epilimnion. The cooler, darker bottom zone is called the hypolimnion. These layers will stay separated until the fall when the upper waters cool, the temperature differences decrease, and the entire lake mixes, or turns over.

From June through September 2000 (the most recent year of available data), temperature was measured at each meter throughout the Sunday Lake water column (see graph). Temperature profiles for 2000 show that the lake was beginning to stratify in June and was moderately stratified from July through September. This means that there was a moderate temperature difference between the warm upper waters and the cooler bottom waters, and mixing was minimal between these layers. In June the upper waters measured about 60°F (15.6°C) in temperature, but by July the upper waters had warmed to 74°F (23°C). The upper waters cooled off slightly in August and September. Throughout the June to September period, bottom water temperatures changed only a little and remained around 53-57°F (12-14°C). These temperature differences show that Sunday Lake stratifies, but not as strongly as deeper lakes.

Each fall the surface waters will continue to cool until the temperatures are almost equal from top to bottom. As stratification weakens, the lake water will turn over (or mix). The lake will stay mixed during the winter until springtime, when the upper waters begin to warm again. This pattern of the upper waters warming in the summer and cooling off in the fall and winter occurs every year, not just in 2000.

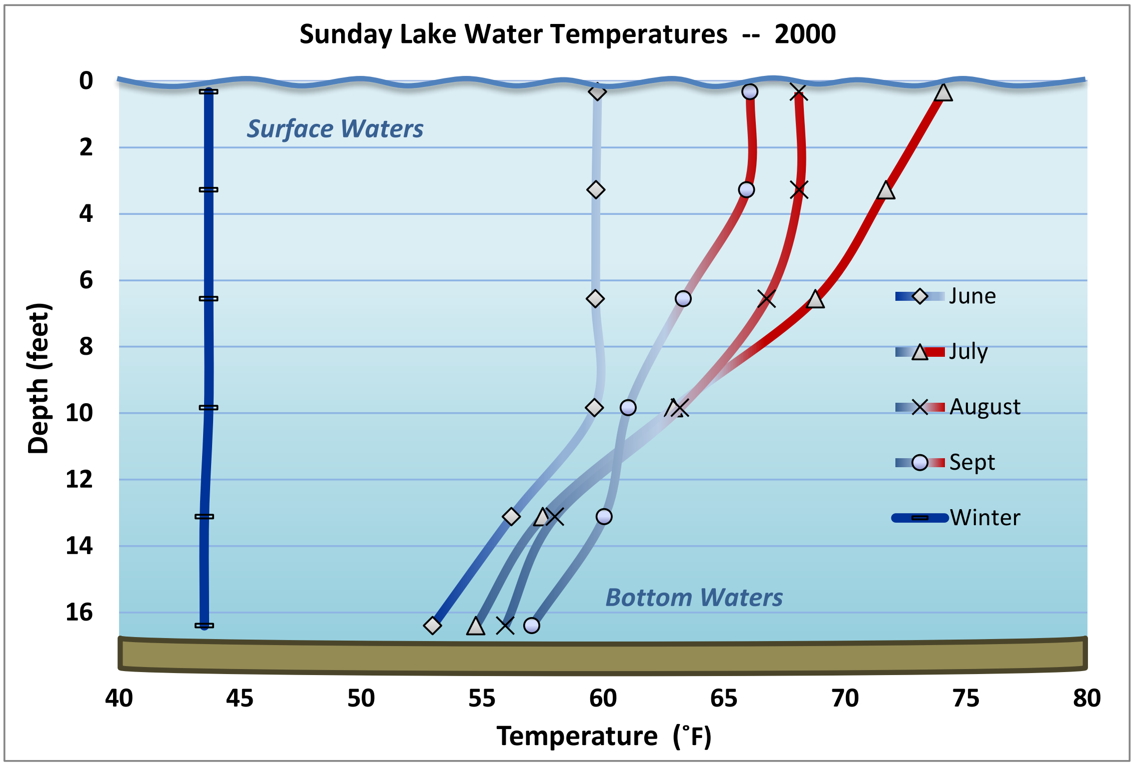
Dissolved Oxygen

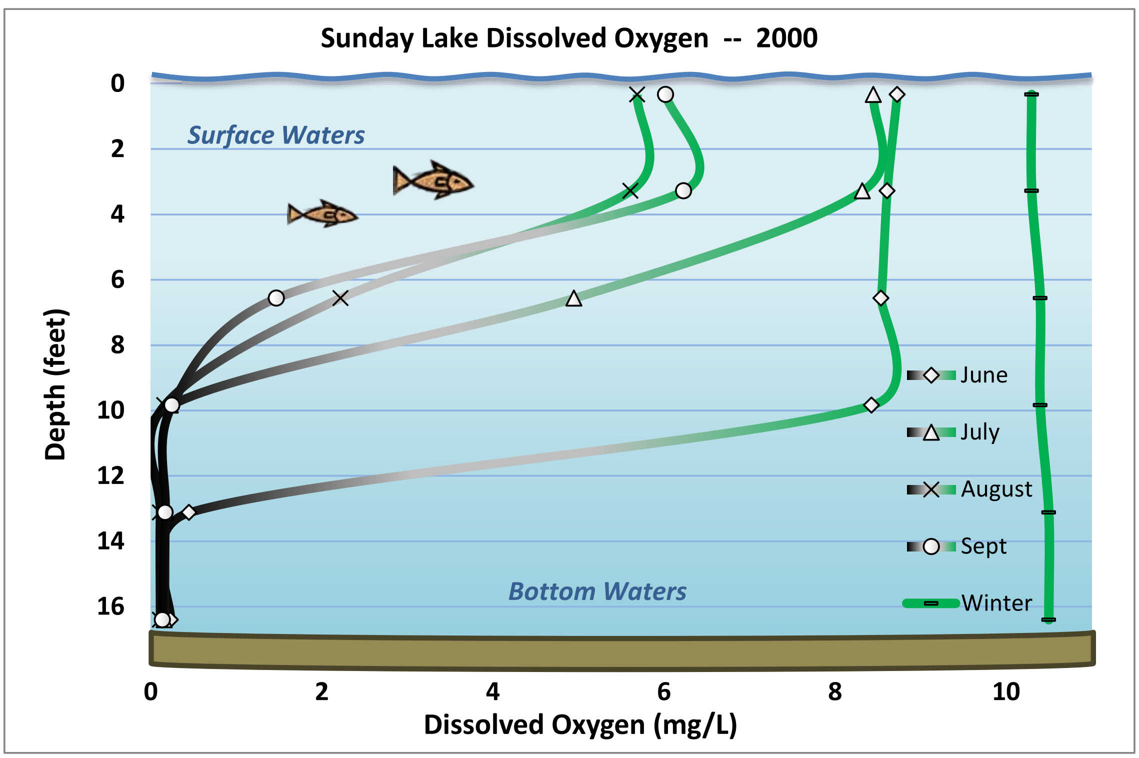
Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished with oxygen because of the separation between water layers. Meanwhile, bacteria in the lake bottom are consuming oxygen as they decompose organic matter. Eventually oxygen is depleted in the bottom waters. Low dissolved oxygen in the bottom waters can lead to a release of nutrients from the lake sediments.

Dissolved oxygen was also measured at every meter throughout the Sunday Lake water column from June to September of 2000 (see graph). Oxygen levels were relatively high in the upper waters in June and July while the bottom waters contained little to no dissolved oxygen. For most of the summer, there was virtually no dissolved oxygen in the lake below about 10 feet deep. During the summer, oxygen in the lower waters is consumed by the decomposition of organic material within the lake. When the lake is stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or the atmosphere. This oxygen deficit even reduced dissolved oxygen levels near the surface in August and September. Very low dissolved oxygen levels in the bottom waters can lead to a release of phosphorus from the lake sediments that can result in increased algae growth in late summer and fall or the next spring.

The bottom of the lake will remain devoid of oxygen until the lake mixes (typically in late October/early November). The lake then remains mixed through the winter until springtime when the upper waters begin to warm and dissolved oxygen begins to decline again near the bottom.

SUNDAY LAKE


Sunday Lake Water Temperatures -- 2000
Surface Waters
Bottom Waters
June
July
August
Sept
Winter
Depth (feet)
0
2
4
6
8
10
12
14
16
40
45
50
55
60
65
70
75
80
Temperature (˚F)

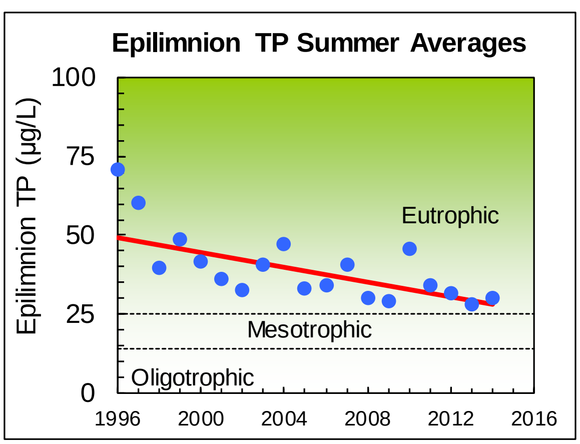

Sunday Lake Dissolved Oxygen -- 2000
Surface Waters
Bottom Waters
June
July
August
Sept
Winter
Depth (feet)
0
2
4
6
8
10
12
14
16
0
2
4
6
8
10
Dissolved Oxygen (mg/L)

SUNDAY LAKE

Phosphorus (key nutrient for algae)

Nutrients are essential for the growth of algae, fish, and aquatic plants in a lake. However, too many nutrients, especially phosphorus, can pollute a lake and lead to unpleasant algae growth. Nutrients enter the lake through stormwater runoff or from streams flowing into the lake. Sources of nutrients include fertilizers, pet and animal wastes, poorly-maintained septic systems, and erosion from land clearing and construction. Monitoring of phosphorus levels over time helps to identify changes in nutrient pollution.

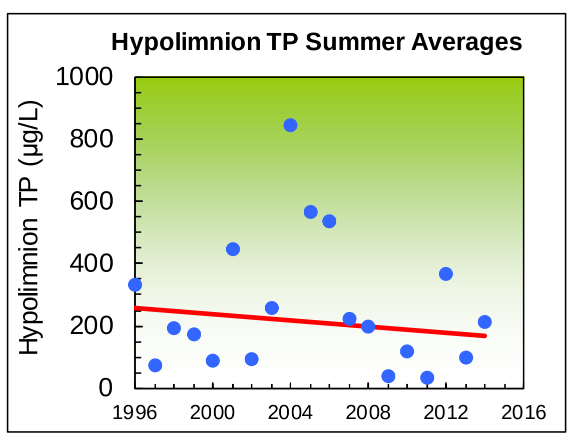
Total phosphorus (TP) levels in Sunday Lake are high. The long-term 1996 - 2014 summer average for total phosphorus in the epilimnion (upper waters) is 40 µg/L (micrograms per liter which is equivalent to parts per billion). Because of high phosphorus levels, Sunday Lake is listed as “impaired” in Washington State’s official 2012 water quality assessment. However, there is evidence that phosphorus levels in the upper waters are declining. Between 1996 and 2014, there has been a statistically significant decrease in phosphorus levels in the upper waters ($p=0.00$). This is good news. However, phosphorus levels continue to be a concern in Sunday Lake because they are high enough to lead to increased algae growth.



Monitoring of the stream entering Sunday Lake during the winters of 2003 - 2004 and 2009 - 2010 showed that relatively high levels of phosphorus are flowing from the watershed. Where the stream crosses 25th Avenue NW, the water had average total phosphorus concentrations in those years of between 53 and 60 µg/L. This is high enough to be contributing additional phosphorus to the lake and increasing the growth of algae and aquatic plants.

Summertime phosphorus levels in the hypolimnion (bottom waters) are very high and more variable than in the upper waters. The long-term 1996 - 2014 summer average is 258 µg/L. Phosphorus levels declined considerably from 2007 through 2011 compared to previous years. In 2012, the summer average was again high at 369 µg/L, but concentrations have been lower in 2013 and 2014.

The variability in phosphorus levels in the bottom waters may be affected by several factors. These include the amount of nutrients coming from the watershed, partial mixing of the lake during wind storms, the degree of oxygen depletion from decaying matter in the lake bottom, the depth of sample collection, and the rise and fall of lake levels because of weather conditions and beaver activity. Overall, between 1996 and 2014 there has been no evidence of a statistically significant trend in phosphorus concentrations in the hypolimnion.

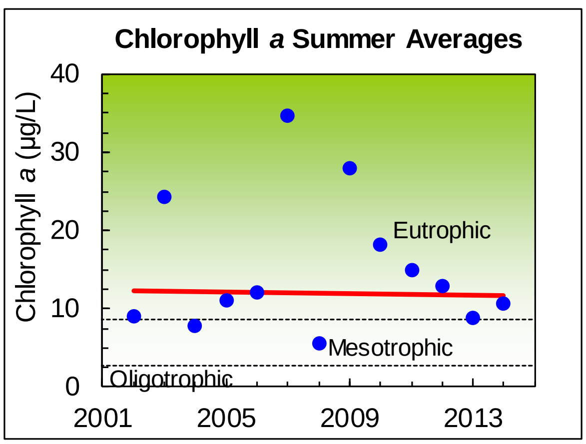


SUNDAY LAKE

Chlorophyll a (Algae)

Algae are tiny plant-like organisms that are essential for a healthy lake. Fish and other lake life depend on algae as the basis for their food supply. However, excessive growths of algae, called algae blooms, can cloud the water, form unsightly scums, and sometimes release toxins. Excess nutrients, such as phosphorus and nitrogen, are the main cause of nuisance algae growth in a lake. Chlorophyll *a* measurements are one method for tracking the amount of algae in a lake.

Chlorophyll *a* values in Sunday Lake are also high, with a long-term 2002 – 2014 summer average of 15 µg/L. The averages in 2007 and 2009 were particularly high and indicate abundant algae production in the lake. Nuisance algae blooms have occurred in Sunday Lake in many years. Overall, there is no evidence of a trend in chlorophyll *a* measurements between 2002 and 2014.



Toxic Blue-Green Algae (Cyanobacteria)

Blue-green algae, also called cyanobacteria, are a group of algae capable of producing toxins during periods of high growth, known as blooms. The toxins can cause serious illness in people and pets that come into contact with affected water. Blooms often look like blue or green paint floating on the surface. Lake users should avoid contact with the water and keep pets away from the lake when it is experiencing a blue-green algae bloom. If a bloom has been identified as toxic, signs will be posted at public access sites.

Since 2005, volunteers and SWM staff have screened algae at Sunday Lake for potentially toxic blooms. During 2010, Sunday Lake tested positive for anatoxin (a nerve toxin) and for cylindrospermopsin (a liver toxin), although the levels were very low. In 2011, Sunday Lake tested positive for both microcystin (another liver toxin) and anatoxin. The microcystin concentrations exceeded the State guideline of 6 µg/L. In November 2012, microcystin was measured at 4.8 µg/L during an algae bloom. No blue-green algae blooms were reported in 2013 or 2014.

Screening for toxic algae will continue in future years as part of the Snohomish County lake monitoring program. Continued monitoring will help alert the public to potential health risks as well as determine the frequency and severity of the toxic algae blooms at Sunday Lake.

Nitrogen (another essential nutrient for algae)

Nitrogen is another important nutrient for plant and algae growth. Similar to phosphorus, lakes with high levels of nitrogen typically have more aquatic plants and algae. In 2014, Sunday Lake had relatively high levels of total nitrogen (summer average of 661 µg/L). This is consistent with the high chlorophyll *a* concentrations measured in the lake. Because of the high nitrogen levels, Sunday Lake is also listed as "impaired" for nitrogen in Washington State's official 2012 water quality assessment.

The relative abundance of nitrogen and phosphorus can also be a useful indicator of lake conditions. This is referred to as the nitrogen to phosphorus ratio or N:P ratio. When lakes have low N:P ratios (typically less than 20), algae growth is often high and harmful blue-green algae blooms may be a problem. Low N:P ratios may also indicate that fertilizers, septic systems, polluted runoff from developed areas, and release of phosphorus from the lake bottom sediments are contributing most of the nutrients to the lake.

In contrast, when lakes have higher N:P ratios (greater than 20), algae growth will be limited by the amount of phosphorus available, and blue-green algae are usually less of a problem. Sunday Lake had a low average N:P ratio of 22 in 2014, which indicates a risk of blue-green algae blooms.

SHORELINE CONDITION

Shoreline conditions are important in understanding overall lake health. Frequently, lake shorelines are modified either through removal of natural vegetation, the installation of bulkheads or other hardening structures, and/or removal of partially submerged logs and branches. These types of alterations can be harmful to the lake ecosystem because natural shorelines protect the lake from harmful pollution, prevent bank erosion, and provide important habitat for fish and wildlife.

Surveys conducted in the mid-90s showed 31 homes bordering Sunday Lake. There are also 17 docks around the lake. Given the level of residential development on the south and west shores, the overall physical shoreline is still relatively intact. Only 22% of the 1.4-mile shoreline has been armored with bulkheads or fills. The zone of native vegetation immediately adjacent to the shoreline has experienced somewhat more modifications. About 62% of the shoreline vegetation has been significantly altered. Also, there is a low amount of large wood still remaining in the lake (about 34 pieces). These old logs and branches are valuable for fish and wildlife habitat.

The shoreline modifications at Sunday Lake leave the lake susceptible to pollution from the watershed, eliminate the buffer of native vegetation that can filter out pollution, and limit the amount of habitat available for fish and wildlife. The loss of native vegetation along the shoreline can also lead to bank erosion.

SUMMARY

Trophic State

All lakes go through a process of enrichment by nutrients and sediment. In this process, known as eutrophication, nutrients and sediment contribute to the ever-increasing growth of algae and aquatic plants. Over thousands of years, lakes will gradually fill up with organic matter and sediments.

Lakes can be classified by their degree of eutrophication, also known as their trophic state. There are three primary trophic states for lakes—oligotrophic, mesotrophic, and eutrophic—as well as intermediate states. Oligotrophic lakes are usually deep, with clear water, low nutrient concentrations, and few aquatic plants and algae. Mesotrophic lakes are richer in nutrients and produce more algae and aquatic plants. Eutrophic lakes are often shallow and characterized by abundant algae and plants, high nutrient concentrations, limited water clarity, and low dissolved oxygen in the bottom waters.

The trophic state classification of a lake does not necessarily indicate good or bad water quality because eutrophication is a natural process. However, human activities that contribute sediment and excess nutrients to a lake can dramatically accelerate the eutrophication process and result in declining water quality.

Based on the long-term monitoring data, Sunday Lake may be classified as eutrophic, with low water clarity, high phosphorus levels, and high productivity of plants and algae. This is the natural condition for this shallow lake, although the lake does experience somewhat more algae growth than should be expected.

SUNDAY LAKE

Condition and Trends

The monitoring data tell a mixed story about Sunday Lake. On the one hand, total phosphorus levels in the epilimnion (upper waters) are declining, which is good for the lake. In contrast, phosphorus in the bottom waters and chlorophyll *a* levels remain high, with no improving trends. And, the main stream flowing into the lake brings abundant nutrients. Taken together, these conditions indicate that the lake is capable of producing excess algae and aquatic plants.

The water quality targets for Sunday Lake are to improve water clarity and reduce phosphorus levels. The lake is meeting the target of lower phosphorus levels in the epilimnion, but not the targets for water clarity or hypolimnetic phosphorus.

Overall, Sunday Lake is in poorer condition than it should be. The lake needs restoration to improve water quality and control the levels of aquatic plants and algae. Reducing the level of nutrients entering the lake would help. In addition to reducing the sources of nutrients, more extensive measures, such as partial dredging of the sediments or addition of aluminum sulfate to the sediments to control the release of phosphorus, may be needed to produce significant improvements in the lake. However, these actions would be very expensive for the local community. Smaller actions taken on individual properties to reduce phosphorus and nitrogen pollution will not completely restore the lake, but will definitely help prevent future declines in water quality. To find out more about the causes and problems of increased phosphorus levels in lakes and tips to improve lake water quality, please visit www.lakes.surfacewater.info.

DATA SUMMARY FOR SUNDAY LAKE

Source	Date	Water Clarity (Secchi depth in meters)	Total Phosphorus (µg/L)		Chlorophyll *a* (µg/L)
			Surface	Bottom	Epilimnion
Bortleson, et al, 1976	**7/26/73**	3.0	18	21	-
DOE	**1990**	0.7 - 3.4 (2.3) *n = 9*	-	-	-
DOE	**1991**	0.6 - 2.9 (2.1) *n = 8*	-	-	-
DOE	**1992**	0.5 - 2.9 (2.4) *n = 8*	-	-	4.3 - 7.8 (6.1) *n = 2*
DOE	**1993**	0.6 - 2.9 (2.3) *n = 11*	-	-	4.8 - 57 (31) *n = 2*
SWM Staff or DOE	**1994**	2.9 - 4.4 (3.7) *n = 3*	-	-	2.6 - 120 (34) *n = 4*
SWM Staff	**1995**	1.7	-	-	33
SWM Staff or Volunteer	**1996**	0.9 - 1.8 (1.4) *n = 5*	54 - 88 (71) *n = 2*	241 - 420 (331) *n = 2*	-
SWM Staff or Volunteer	**1997**	0.8 - 1.7 (1.2) *n = 10*	55 - 66 (61) *n = 2*	56 - 92 (74) *n = 2*	-
SWM Staff or Volunteer	**1998**	0.6 - 1.5 (1.0) *n = 8*	31 - 61 (40) *n = 4*	117 - 352 (195) *n = 4*	-
SWM Staff	**1999**	0.8 - 1.7 (1.3) *n = 4*	38 - 66 (49) *n = 4*	118 - 306 (175) *n = 4*	-
SWM Staff	**2000**	1.6 - 2.0 (1.8) *n = 4*	17 - 89 (42) *n = 4*	35 - 194 (89) *n = 4*	-
Volunteer	**2001**	1.2 - 2.0 (1.6) *n = 4*	24 - 58 (36) *n = 4*	77 - 842 (445) *n = 4*	-
SWM Staff or Volunteer	**2002**	1.6 - 2.5 (2.2) *n = 4*	24 - 51 (33) *n = 4*	37 - 137 (96) *n = 4*	2.7 - 22 (9.1) *n = 4*
Volunteer	**2003**	1.2 - 2.6 (1.8) *n = 9*	27 - 64 (41) *n = 6*	38 - 596 (258) *n = 6*	8.3 - 71 (24) *n = 6*
Volunteer	**2004**	1.0 - 1.7 (1.4) *n = 3*	26 - 81 (47) *n = 3*	356 - 1388 (847) *n = 3*	2.1 - 15 (7.8) *n = 3*
Volunteer	**2005**	1.1 - 2.5 (1.6) *n = 5*	29 - 37 (33) *n = 4*	116 - 1010 (567) *n = 4*	3.2 - 31 (11) *n = 4*

SUNDAY LAKE

DATA SUMMARY FOR SUNDAY LAKE					
		Water Clarity (Secchi depth	**Total Phosphorus (µg/L)**		**Chlorophyll *a* (µg/L)**
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Epilimnion**
Volunteer	**2006**	1.5 - 2.1 (1.8) *n = 4*	24 - 53 (34) *n = 4*	147 - 791 (537) *n = 4*	4.8 - 25 (12) *n = 4*
SWM Staff	**2007**	0.8 - 2.2 (1.7) *n = 4*	31 - 50 (41) *n = 4*	30 - 745 (225) *n = 4*	6.1 - 73 (35) *n = 4*
SWM Staff	**2008**	2.2 - 2.6 (2.5) *n = 4*	23 - 41 (30) *n = 3*	50 - 484 (197) *n = 4*	2.7 - 11 (5.6) *n = 4*
Volunteer	**2009**	1.3 - 3.2 (2.3) *n = 12*	25 - 33 (29) *n = 3*	25 - 48 (37) *n = 2*	9.9 - 37 (28) *n = 3*
Volunteer	**2010**	1.7 - 2.1 (1.9) *n = 4*	38 - 55 (46) *n = 4*	42 - 226 (120) *n = 4*	14 - 23 (18) *n = 4*
Volunteer	**2011**	1.1 - 3.2 (2.1) *n = 7*	30 - 40 (34) *n = 4*	26 - 41 (34) *n = 2*	9.1 - 27 (15) *n = 4*
Volunteer	**2012**	1.3 - 2.7 (2.0) *n = 6*	25 - 41 (32) *n = 4*	117 - 620 (369) *n = 2*	6.4 - 19 (13) *n = 4*
Volunteer	**2013**	1.4 - 2.3 (2.1) *n = 5*	24 - 32 (28) *n = 4*	51 - 160 (97) *n = 4*	1.6 - 27 (8.9) *n = 4*
Volunteer	**2014**	1.4 - 2.2 (1.7) *n = 3*	25 - 36 (30) *n = 3*	25 - 538 (214) *n = 3*	6.4 - 18 (11) *n = 3*
Long Term Avg		**1.9** **(1990-2014)**	**40** **(1996-2014)**	**258** **(1996-2014)**	**15** **(2002-2014)**
TRENDS		**None**	**Decreasing**	**None**	**None**

NOTES

- Table includes summer (May-Oct) data only.
- Each box shows the range on top, followed by summer average in ( ) and number of samples (*n*).
- Total phosphorus data are from samples taken at discrete depths only.
- DOE = Washington Department of Ecology
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.